SEISMIC HAZARD ZONE REPORT FOR THE SAN JOSE WEST 7.5-MINUTE QUADRANGLE, SANTA CLARA COUNTY, CALIFORNIA

2002

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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SEISMIC HAZARD ZONE REPORT 058

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EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the San Jose West 7.5-minute Quadrangle, Santa Clara County, California. The map displays the boundaries of Zones of Required Investigation for liquefaction and earthquake-induced landslides over an area of approximately 60 square miles at a scale of 1 inch = 2,000 feet.

The San Jose West 7.5-minute Quadrangle covers an area of densely urbanized land in western Santa Clara County, California, south of San Francisco Bay. The City of San Jose, including the civic center and downtown area, covers most of the quadrangle. The southern part of the City of Santa Clara is in the northwestern corner of the quadrangle and the entire City of Campbell is in the south-central part of the quadrangle. Parts of the cities of Los Gatos, Saratoga, and Sunnyvale also extend into the southern and western margins of the quadrangle. Most of the area is underlain by alluvial fan deposits within the broad Santa Clara Valley that slope gently northward toward the bay. Numerous creeks and streams drain the Santa Clara Valley. The only hilly terrain within the quadrangle is a small triangular area of about 2 square miles of Santa Cruz Mountains foothills in the southwestern corner. A dense network of freeways, arterial roadways and city streets provides access. The San Jose International Airport is also within the quadrangle.

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years.

The liquefaction zone boundary primarily coincides with the 30-foot ground-water depth contour in the central part of the San Jose West Quadrangle. Therefore, nearly the northern third of the quadrangle is in the zone of required investigation. Elsewhere, stream channel deposits and other young alluvial units, where the water table is less than 40 feet, are also within the zone. Locally, liquefaction effects were observed within the quadrangle during earthquakes in 1906 and 1989. Fourteen landslides were mapped within a 2-square mile area in the foothills of the Santa Cruz Mountains. The earthquake-induced landslide zone is restricted to the steeper slopes of the foothills and areas along creek banks in the central portion of the quadrangle. The landslide zone of required investigation covers only about 1% of the quadrangle because most of the quadrangle is not hilly.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet page: http://www.consrv.ca.gov/dmg/shezp/

Paper copies of Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

> BPS Reprographic Services
> 149 Second Street
> San Francisco, California 94105
> (415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the San Jose West 7.5-minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the San Jose West 7.5-Minute Quadrangle, Santa Clara County, California

By
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California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the San Jose West 7.5-minute Quadrangle. This section, along with Section 2 (addressing earthquake-induced landslides), and Section 3 (addressing potential ground shaking), form a report that is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on DMG's Internet web page: http://www.consrv.ca.gov/dmg/ shezp/

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in northern California. During the 1989 Loma Prieta and 1906 San Francisco earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the San Francisco Bay Area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions are widespread in the San Francisco Bay Area, most notably in alluviated valley floodplains and around the margin of the bay. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the San Francisco Bay Area, including areas in the San Jose West Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill.

- Construction of shallow ground-water maps showing the historically highest known ground-water levels.

- Quantitative analysis of geotechnical data to evaluate liquefaction potential of deposits.

- Information on potential ground shaking intensity based on DMG probabilistic shaking maps.

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the San Jose West Quadrangle consist mainly of alluviated valleys and floodplains.

DMG's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The San Jose West Quadrangle includes nearly 60 square miles of urbanized terrain in Santa Clara County, California. The city of San Jose, including the downtown area, covers much of the quadrangle. The southern portion of the city of Santa Clara is in the northwest part of the quadrangle and the entire city of Campbell is in the south-central area of the quadrangle. Parts of the cities of Los Gatos, Saratoga, and Sunnyvale are along the southern and western margins of the quadrangle.

The broad Santa Clara Valley occupies most of the quadrangle and contains alluvial fan deposits that slope down gently to the north toward San Francisco Bay. Five creeks (Calabazas, Saratoga, Los Gatos, San Tomas Aquinas, Coyote) and the Guadalupe River, along with numerous intermittent streams, crosss the Santa Clara Valley in this area. Saratoga, Los Gatos, Calabazas, and San Tomas Aquinas creeks, and the Guadalupe River originate in the Santa Cruz Mountains on the western margin of the Santa Clara Valley, whereas Coyote Creek originates in the Diablo Range on the eastern margin of the valley. These streams flow northward into the tidal marshes at the active margin of San Francisco Bay. A small portion of the foothills of the Santa Cruz Mountains occupies the southwestern corner of the quadrangle.

Three freeways and several other arterial roadways cross the map area. Northwesterly trending U.S. Highway 101 (Bayshore Freeway) intersects Highway 17/Interstate 880 in the northeast corner of the quadrangle. Highway 17 extends southwest through the central portion of the quadrangle to the southern margin. Interstate Highway 280 (Junipero Serra) extends east-west across the center of the quadrangle. A network of secondary roads links these major highways. The San Jose International Airport is in the north-central part of the quadrangle.

GEOLOGY

Bedrock and Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. To evaluate the areal and vertical distribution of shallow Quaternary deposits in the San Jose West Quadrangle, recently completed maps of the nine-county San Francisco Bay Area showing Quaternary deposits (Knudsen and others, 2000) and bedrock units (Wentworth and others, 1999) were obtained from the U.S. Geological Survey in digital form. These GIS maps were combined, with minor modifications along the bedrock/Quaternary contact, to form a single, 1:24,000-scale geologic map of the San Jose West Quadrangle. The distribution of Quaternary deposits on this map (summarized on Plate 1.1) was used in combination with other data, discussed below, to evaluate liquefaction and develop the Seismic Hazard Zone Map.

The Quaternary geologic mapping methods described by Knudsen and others (2000) consist of interpretation of topographic maps, aerial photographs, and soil surveys, as well as compiled published and unpublished geologic maps. The authors estimate the ages of deposits using: landform shape, relative geomorphic position, crosscutting relationships, superposition, depth and degree of surface dissection, and relative degree of soil profile development. Table 1.1 compares stratigraphic nomenclature used in Knudsen and others (2000) and the DMG GIS database, with that of several previous studies performed in northern California.

Other geologic maps and reports were reviewed to evaluate the areal and vertical distribution of shallow Quaternary deposits and to provide information on subsurface geologic, lithologic and engineering properties of the units. Among the references consulted were Crittenden (1951), California Department of Water Resources (1967), Helley and Brabb (1971), Poland (1971), Nilsen and Brabb (1972), Brown and Jackson (1973), Cooper-Clark & Associates (1974), Rogers and Williams (1974), Atwater and others (1976), Helley and others (1979), Falls (1988), Wesling and Helley (1989), Helley (1990), Geomatrix Consultants Inc. (1992a, 1992b), Helley and others (1994), and Iwamura (1995). Limited field reconnaissance was conducted to confirm the location of geologic contacts, map recently modified ground surfaces, observe properties of near-surface deposits, and characterize the surface expression of individual geologic units.

UNIT	Knudsen and others (2000)	Helley and others (1994)	Wesling and Helley (1989)	Helley and others (1979)	Wentworth and others (1999)	DMG GIS database
Artificial fill	af		Qha		af	af
Artificial fill, levee	alf					alf
Gravel quarries and percolation ponds	gq	PP,GP			PP,GP	gq
Artificial stream channel	ac					ac
Modern stream channel deposits	Qhc	Qhsc		Qhsc	Qhc	Qhc
Latest Holocene alluvial fan levee deposits	Qhly					Qhly
Latest Holocene stream terrace deposits	Qhty					Qhty
Holocene basin deposits	Qhb	Qhb	Qhb, Qhbs		Qhb	Qhb
Holocene alluvial fan deposits	Qhf	Qhaf, Qhfp	Qhaf, Qhal	Qham, Qhac	Qhf, Qhfp	Qhf
Holocene alluvial fan deposits, fine grained facies	Qhff	Qhb		Qhaf	Qhb	Qhff
Holocene alluvial fan levee deposits	Qhl	Qhl			Qh1	Qhl
Holocene stream terrace deposits	Qht	Qhfp	Qhfp1, Qhfp2		Qht	Qht
Holocene alluvium, undifferentiated	Qha				Qha	Qha
Late Pleistocene to Holocene alluvial fan deposits	Qf					Qf
Late Pleistocene to Holocene stream terrace deposits	Qt					Qt
Late Pleistocene to Holocene alluvium, undifferentiated	Qa				Qa	Qa
Late Pleistocene alluvial fan deposits	Qpf	Qpaf	Qpaf		Qpf	Qpf
Early to middle Pleistocene alluvial	Qof		Qpaf	Qof	Qof	Qof
Bedrock	br	br				

Table 1.1. Correlation Chart of Quaternary Stratigraphic Nomenclatures Used in Previous Studies. For this study, DMG has adopted the nomenclature of Knudsen and others (2000).

In the San Jose West Quadrangle there are 16 Quaternary units mapped by Knudsen and others (2000). Coalescing late Pleistocene and Holocene alluvial fans form a northeastward-sloping bajada that covers much of the western and southern parts of the quadrangle. From west to east, the creeks that supply sediment to the alluvial fans are Calabazas, Saratoga, Tomas Aquinas, Los Gatos, and Ross. Near the heads of the fans, creeks have incised large, latest Pleistocene alluvial fan deposits (Qpf) consisting of coarse sand and gravel. Farther upstream, a few small upland valleys containing undifferentiated late Pleistocene to Holocene alluvium (Qa), are mapped in the foothills of the Santa Cruz Mountains. Stream terrace deposits (Qhty, Qht, and Qt) are mapped in the upper reaches of San Tomas Aquinas and Los Gatos creeks.

Sediment along the eastern margin of the quadrangle has been deposited near the axis of the Santa Clara Valley by the Guadalupe River, and in the northeastern corner of the quadrangle, by Coyote Creek. In the distal areas of Coyote Creek and the Guadalupe River, narrow latest Holocene alluvial fan levee deposits (Qhly) grade laterally into Holocene alluvial fan levee deposits (Qhl) and fine-grained, Holocene alluvial fan deposits (Qhff) (Knudsen and others, 2000).

Artificial levee fill (alf), and artificial stream channels (ac) are mapped along a few of the major streams (Knudsen and others, 2000). To accommodate larger flows in the winter months, some reaches of these watercourses have been confined within concrete-lined structures as much as 30 feet deep that commonly have artificial levees along their banks.

Bedrock exposed in the San Jose West Quadrangle consists of Plio-Pleistocene Santa Clara Formation (Wentworth and others, 1999). This unit is exposed in the Santa Cruz Mountain foothills in the southwestern part of the quadrangle and consists of fluvial boulder to pebble conglomerate, sandstone, and siltstone. See the Earthquake Induced Landslide portion (Section 2) of this report for discussion of bedrock geology.

Structural Geology

The San Jose West Quadrangle is within the active San Andreas Fault system, which distributes shearing across a complex system of primarily northwest-trending, right-lateral, strike-slip faults that include the San Andreas, Hayward, and Calaveras faults. The San Andreas Fault lies approximately two miles west of the San Jose West Quadrangle, and the Hayward and Calaveras faults are approximately six miles and eight miles to the east, respectively. Historical ground surface-rupturing earthquakes have occurred on all of these faults (Lawson, 1908; Keefer and others, 1980). Several oblique-slip and reverse-slip faults, including the Berrocal, Shannon, Monte Vista, and Santa Clara faults, are within or slightly west of the quadrangle along the base of the foothills (McLaughlin and others, 1991; Hitchcock and others, 1994; Campbell and others, 1995).

ENGINEERING GEOLOGY

Information on subsurface geology and engineering characteristics of flatland deposits was obtained from borehole logs collected from reports on geotechnical and environmental projects. For this investigation, about 230 borehole logs were collected from the files of the California Department of Transportation (CalTrans) and the cities of San Jose and Santa Clara. Data from 211 borehole logs were entered into a DMG geotechnical GIS database.

Standard Penetration Test (SPT) (ASTM D1586, American Society for Testing Materials, 1999) data provide a standardized measure of the penetration resistance of a geologic deposit and commonly are used as an index of density. Many geotechnical investigations record SPT data, including the number of blows required for a 140-pound weight dropped 30 inches to drive a sampler of specific dimensions one foot into the soil. Recorded blow counts for non-SPT geotechnical sampling, where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT, were converted to SPT-equivalent blow count values when feasible and entered into the DMG GIS. The actual and converted SPT blow counts were normalized to a common reference effective overburden pressure of one atmosphere (approximately one ton per square foot) and a hammer efficiency of 60% using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

Geotechnical and environmental borehole logs provided information on lithologic and engineering characteristics of Quaternary deposits within the study area. Geotechnical characteristics of the Quaternary map units are generalized in Tables 1.2 and 1.3. Analysis of the data in Tables 1.2 and 1.3 exposes contrasts among the units, including: 1) an abundance of fine-grained material within the Holocene units; 2) Holocene materials are less dense and more readily penetrated than Pleistocene materials; 3) Pleistocene units are predominantly coarse grained; and 4) Holocene alluvial fan deposits (Qhf) have a higher percentage of fine-grained materials and are denser than Holocene alluvial fan levee deposits (Qhl).

GEOLOGIC MAP UNIT		DRY DENSITY (pounds per cubic foot)						STANDARD PENETRATION RESISTANCE (blows per foot, $(N_1)_{60}$)					
Unit (1)	Texture (2)	Number of Tests	Mean	CV (3)	Median	Min	Max	Number of Tests	Mean	CV (3)	Median	Min	Max
af	Fine	16	102.2	0.09	103	88.4	119	22	32	0.95	24	2	>99
	Coarse	3	114	0.09	109	107	126	6	62	0.92	34	28	>99
Qhly	Fine	2	95.5	0.08	95.5	90	101	6	22	0.42	19	12	36
	Coarse	1	109	-	-	-	-	2	19	0.31	19	15	23
Qhty	Fine	-	-	-	-	-	-	-	-	-	-	-	-
	Coarse	-	-	-	-	-	-	3	8	0.21	8	6	9
Qhb	Fine	-	-	-	-	-	-	1	19	-	-	-	-
	Coarse	-	-	-	-	-	-	-	-	-	-	-	-
Qhf	Fine	295	98.8	0.11	100	64	124	527	18	0.79	14	3	>99
	Coarse	69	106.4	0.10	107.8	81	129.5	205	24	0.98	18	2	>99
Qhff	Fine	28	94.8	0.12	93.5	71	111.2	63	25	0.76	20	3	87
	Coarse	-	-	-	-	-	-	-	-	-	-	-	-
Qhl	Fine	39	103.8	0.10	104.6	85	124.7	73	17	0.64	15	3	61
	Coarse	16	102.7	0.07	103.6	90	114	48	19	0.88	14	2	95
Qf	Fine	16	105.4	0.07	103	88	119.1	23	18	0.75	15	3	62
	Coarse	10	117.8	0.07	117	104	131	26	33	0.73	26	8	>99
Qt	Fine	-	-	-	-	-	-	-	-	-	-	-	-
	Coarse	1	114	-	-	-	-	2	27	0.22	27	23	31
Qpf	Fine	45	105.3	0.09	104	75	133	39	29	0.66	22	6	88
	Coarse	50	118.7	0.09	120.5	94.7	140	132	42	0.56	36	7	>99

Notes:
(1) See Table 1.3 for names of the units listed here.
(2) Fine soils (silt and clay) contain a greater percentage passing the #200 sieve (<.0.074 mm); coarse soils (sand and gravel) contain a greater percentage not passing the #200 sieve.
(3) CV = coefficient of variation (standard deviation divided by the mean).

Table 1.2. Summary of Geotechnical Characteristics for Quaternary Geological Map Units in the San Jose West 7.5-Minute Quadrangle.

Geologic Map Unit (1)	Description	Number of Records	Composition by Soil Type (Unified Soil Classification System)	Depth to ground water (ft) and liquefaction susceptibility category assigned to geologic unit (2)			
				<10	10 to 30	30 to 40	>40
af	Artificial fill (3)	48	CL 52%; SP 8%; Other 40%	VH - L	H - L	M - L	VL
alf	Artificial fill, levee	0	n/a (4)	VH	H	M	VL
gq	Gravel quarries and percolation ponds	0	n/a (4)	VH	H	M	VL
ac	Artificial stream channel	0	n/a (4)	VH	H	M	VL
Qhc	Modern stream channel deposits	0	n/a (4)	VH	H	M	VL
Qhly	Latest Holocene alluvial fan levee deposits	8	CL 63%; Other 37%	VH	H	M	VL
Qhty	Latest Holocene stream terrace deposits	3	ML 33%; SM 34% SP-SM 33%	VH	H	M	VL
Qhb	Holocene basin deposits	2	CL 50%; OL 50%	M	L	L	VL
Qhf	Holocene alluvial fan deposits	752	CL 44%; ML 14% SM 13%; Other 29%	H	M	L	VL
Qhff	Holocene alluvial fan deposits, fine facies	51	CL 49%; CH 39% ML 10%; Other 2%	M	M	L	VL
Qhl	Holocene alluvial fan levee deposits	119	CL 29%; ML 24%; SM 27%; Other 20%	H	M	L	VL
Qht	Holocene stream terrace deposits	0	n/a (4)	H	H	M	VL
Qha	Holocene alluvium, undifferentiated	0	n/a (4)	M	M	L	VL
Qf	Late Pleistocene to Holocene alluvial fan deposits	26	CL 54%; SM 15% SP 12%; Other 19%	M	L	L	VL
Qt	Late Pleistocene to Holocene stream terrace deposits	2	SC 50%; SP 50%	M	L	L	VL
Qa	Late Pleistocene to Holocene alluvium, undifferentiated	0	n/a (4)	M	L	L	VL
Qpf	Late Pleistocene alluvial fan deposits	259	CL 27%; SM- SP 27%; GC-GM-GP-GW 21%; Other 25%	L	L	VL	VL
Qof	Early to middle Pleistocene alluvial fan deposits	0	n/a (4)	L	L	VL	V L
B	Bedrock	n/a (4)	n/a (4)	VL	VL	VL	VL

Notes:

(1) Susceptibility assignments are specific to the materials within the San Jose West 7.5-minute Quadrangle.

(2) Based on the Simplified Procedure (Seed and Idriss, 1971; Youd and Idriss, 1997) and borehole analyses for some units. For units where subsurface information is not available, susceptibility is based on soil characteristics of similar deposits.

(3) The liquefaction susceptibility of artificial fill ranges widely, depending largely on the nature of the fill, its age, and whether it was compacted during emplacement.

(4) n/a = not applicable

Table 1.3. Liquefaction Susceptibility for Quaternary Map Units within the San Jose West 7.5-Minute Quadrangle. Units indicate relative susceptibility of deposits to liquefaction as a function of material type and ground water depth within that deposit. VH = very high, H = high, M = moderate, L = low, and VL = very low to none.

GROUND-WATER CONDITIONS

Liquefaction hazard may exist in areas where depth to ground water is 40 feet or less. DMG uses the highest known ground-water levels because water levels during an earthquake cannot be anticipated because of the unpredictable fluctuations caused by natural processes and human activities. A historical-high ground-water map differs from most ground-water maps, which show the actual water table at a particular time. Plate 1.2 depicts a hypothetical ground-water table within alluviated areas.

Ground-water conditions were investigated in the San Jose West Quadrangle to evaluate the depth to saturated materials. Saturated conditions reduce the effective normal stress, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973). The evaluation was based on first-encountered water noted in geotechnical borehole logs acquired from CalTrans and the cities of San Jose and Santa Clara, and water-level data provided by the Santa Clara Valley Water District. The depths to first-encountered unconfined ground water were plotted onto a map of the project area to constrain the estimate of historically shallowest ground water. Water depths from boreholes known to penetrate confined aquifers were not included.

Ground-water levels are currently at or near their historical highs in many areas of the Santa Clara Valley. The Santa Clara Valley Water District recently has observed artesian wells, which are reflective of rising ground-water levels (Seena Hoose, Santa Clara Valley Water District, oral communication, 2000). Regional ground-water contours on Plate 1.2 show historically highest ground-water depths, as interpreted from borehole logs from investigations between the 1950s and 2000.

Depths to first-encountered water range from more than 100 feet to as little as 4 feet below the ground surface (Plate 1.2). In general, the proximity of San Francisco Bay to the north influences the ground-water levels in the northern one-third of the quadrangle. Ground-water levels increase sharply near the center of the quadrangle. They are deepest, greater than 40 feet, in the central portion of the quadrangle and along the west-southwestern part of the quadrangle along the base of the foothills (Plate 1.2).

The Santa Clara Valley ground-water basin is fed by water that infiltrates the subsurface primarily from streams and man-made percolation ponds near the foothills. The southern part of the San Jose West Quadrangle is such a recharge area, with unconfined ground-water conditions and discontinuous aquitards. In the central and northern part of the quadrangle, in the subsurface, a fine-grained, alluvial fan unit dipping subparallel to the ground surface serves as a thick aquitard between two distinct coarse-grained aquifer "zones" (Iwamura, 1995). Above the aquitard, discontinuous shallow aquifers within clayey deposits account for the steep ground-water gradient northwest of the freeway interchange in the center of Plate 1.2. The ground-water level in the upper aquifer zone may, in part, be controlled by sea level.

PART II

LIQUEFACTION HAZARD POTENTIAL

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. DMG’s method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the State Mining and Geology Board (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment’s geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. DMG's qualitative relations among susceptibility, geologic map unit and depth to ground water are summarized in Table 1.3.

Most Holocene materials within the quadrangle, where water levels are within 30 feet of the ground surface, have susceptibility assignments of high (H) to very high (VH) (Table 1.3). This differs from Geomatrix Consultants, Inc., 1992b) susceptibility assignments. Geomatrix Consultants, Inc., 1992b) mapped Holocene alluvial fan deposits with the water table more than 10 feet below the ground surface as having low susceptibility. They also used a different ground-water contour map. These differences in susceptibility mapping are evident in dissimilar positions of the susceptibility-level boundaries mapped by Geomatrix Consultants, Inc., 1992b) and the seismic hazard zone lines mapped for this study in the central and northern parts of the quadrangle.

Holocene alluvial fan fine-facies deposits (Qhff), basin deposits (Qhb), and undifferentiated alluvium (Qha) are primarily fine-grained material and have correspondingly lower susceptibility assignments. They may, however, contain lenses of material with higher liquefaction susceptibility. Holocene alluvial fan deposits (Qhf) and alluvial fan levee deposits (Qhl) have a moderate susceptibility assignment where ground water is between 10 and 30 feet below the ground surface. Late Pleistocene to Holocene undifferentiated alluvium (Qa) and stream terrace deposits (Qt) have low densities along with lenses of potentially liquefiable material and, therefore, are assigned moderate susceptibility. All late Pleistocene and older deposits have low (L) to very low (VL) susceptibility assignments.

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in DMG's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the San Jose West Quadrangle, PGAs of 0.55g to 0.66g, resulting from a earthquake of magnitude 7.9, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996). See the ground motion portion (Section 3) of this report for further details.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). Using the Seed-Idriss Simplified Procedure one can calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, DMG's analysis uses the Idriss magnitude scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS = (CRR / CSR) * MSF. FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures. The DMG liquefaction analysis program calculates an FS for each geotechnical sample for which blow counts were collected. Typically, multiple samples are collected for each borehole. The lowest FS in each borehole is used for that location. FS values vary in reliability according to the quality of the geotechnical data used in their calculation. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

Of the 211 geotechnical borehole logs reviewed in this study (Plate 1.2), 193 include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2½-inch inside-diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (e.g. soil density, moisture content, sieve analysis, etc.) required for an ideal Seed-Idriss Simplified Procedure. For boreholes having acceptable penetration tests, liquefaction analysis is performed using recorded density, moisture, and sieve test values or using averaged test values of similar materials.

The Seed-Idriss Simplified Procedure for liquefaction evaluation was developed for primarily clean sand and silty sand. As described above, results depend greatly on accurate evaluation of in-situ soil density as measured by the number of soil penetration blow counts using an SPT sampler. However, many of the Holocene alluvial deposits in the study area contain a significant amount of gravel. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of these soils presumably would allow the dissipation of pore pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during earthquakes, and recent laboratory studies have shown that gravelly soils are susceptible to liquefaction (Ishihara, 1985; Harder and Seed, 1986; Budiman and Mohammadi, 1995; Evans and Zhou, 1995; and Sy and others, 1995). SPT-derived density measurements in gravelly soils are unreliable and generally too high. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes

2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the San Jose West Quadrangle is summarized below.

Areas of Past Liquefaction

Tinsley and others (1998) compiled observations of evidence for liquefaction in the San Jose West Quadrangle for the 1989 Loma Prieta earthquake, and Youd and Hoose (1978) compiled them for the 1868 and 1906 earthquakes. During the 1989 Loma Prieta earthquake, two areas near the southeast corner of the San Jose Municipal Airport experienced liquefaction. Features suggesting probable liquefaction were observed on the east bank of the Guadalupe River and minor lateral spreading and settlement occurred along the airport frontage road (Tinsley and others, 1998). No damage was reported on the airport grounds or to the airport structures (Seed and others, 1990).

Youd and Hoose (1978) report that following the 1906 earthquake, water and mud spurted from artesian wells in the Willow Park area of San Jose, east of the Guadalupe River as reported in Lawson (1908). Numerous cracks indicative of lateral spreading developed along the banks of the Coyote River in the northeast corner of the quadrangle. Youd and Hoose (1978) also report that San Jose’s water works, sewers, and gas lines were not damaged by the 1906 earthquake.

Artificial Fills

In the San Jose West Quadrangle, artificial fill areas large enough to show at the scale of mapping consist of engineered fill for river levees and elevated freeways. Since these fills are properly engineered, zoning for liquefaction in such areas depends on soil conditions in underlying strata. Non-engineered fills are commonly loose and uncompacted and the material varies in size and type.

Areas with Sufficient Existing Geotechnical Data

Borehole logs that include penetration test data and sufficiently detailed lithologic descriptions were used to evaluate liquefaction potential. These areas with sufficient geotechnical data were evaluated for zoning based on the liquefaction potential determined by the Seed-Idriss Simplified Procedure. In Holocene alluvial deposits that cover much of the San Jose West Quadrangle, most of the borehole logs that were analyzed using the Seed-Idriss Simplified Procedure and have ground water and contain sediment layers that may liquefy under the expected earthquake loading. Those areas containing saturated potentially liquefiable material, as shown in Table 1.3, are included in the zone.

In the central part of the quadrangle, the liquefaction zone boundary coincides with the 30-foot ground-water contour that crosses the coalescing fan, except in the area between highways 17 and 87. The liquefaction zone boundary in the latter area is delineated by the depth to denser material, primarily late Pleistocene alluvial fan deposits (Qpf), and the depth to ground water. Areas are excluded from the zone where lower density, younger material is above the water table (i.e. unsaturated) and only denser Pleistocene material is saturated.

Areas with Insufficient Existing Geotechnical Data

Adequate geotechnical borehole information for the southern alluvial fan area where ground water is above 40 feet generally is lacking. Soil characteristics are assumed to correspond to similar deposits where subsurface information is available. At the head of the fan along Los Gatos, San Tomas Aquinas, and an unnamed creek, late Pleistocene to Holocene stream terrace deposits (Qt), late Pleistocene to Holocene undifferentiated alluvium (Qa), Holocene stream terrace deposits (Qht), late Holocene stream terrace deposits (Qhty), undifferentiated Holocene alluvium (Qha), Holocene alluvial fan levee deposits (Qhl), and modern stream channel deposits (Qhc) are included in the liquefaction zone for reasons presented in criterion 4-a, above. Conversely, late Pleistocene alluvial fan deposits (Qpf) located along the base of the foothills are not included in the liquefaction zone for reasons presented in criterion 4-c, above.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the San Jose West 7.5-Minute Quadrangle, Santa Clara County, California

By
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California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This Section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the San Jose West 7.5-minute Quadrangle (scale 1:24,000). This section, along with Section 1 (addressing liquefaction), and Section 3 (addressing earthquake shaking), form a report that is one of a series that summarize the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/.

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the San Jose West Quadrangle.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area.

- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing landslides, whether triggered by earthquakes or not, was prepared.

- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area.

- Seismological data in the form of DMG probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area.

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the

Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide hazard potential map according to criteria developed in a DMG pilot study (McCrink and Real, 1996) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the San Jose West Quadrangle, for more information on the delineation of liquefaction zones.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the San Jose West Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone map.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The San Jose West 7.5-minute Quadrangle includes approximately 60 square miles of urbanized land in western Santa Clara County, California, at the southern end of San Francisco Bay. The city of San Jose, including the downtown area, covers most of the quadrangle and portions of other cities cover the remainder. The southern portion of the city of Santa Clara is in the northwest part of the quadrangle and the entire city of Campbell is in the south-central part of the quadrangle. Parts of the cities of Los Gatos, Saratoga, and Sunnyvale are along the southern and western margins of the quadrangle.

Most of the quadrangle is covered by of alluvial fan deposits in the broad Santa Clara Valley that slope gently northward toward the bay. Calabazas, Saratoga, Los Gatos, San Tomas Aquinas, and Coyote creeks and the Guadalupe River, along with numerous intermittent streams, cross the Santa Clara Valley in this area. Saratoga, Los Gatos, Calabazas and San Tomas Aquinas creeks and the Guadalupe River originate in the Santa Cruz Mountains on the western margin of the Santa Clara Valley, whereas Coyote Creek originates in the Diablo Range on the eastern margin of the valley. These streams flow northward into the tidal marshes around the margin of San Francisco Bay.

A small triangular portion of the foothills of the Santa Cruz Mountains forms an upland area of about 2 square miles in the southwestern corner of the quadrangle. Northwest-sloping rolling terrain has been modified by stream incision, producing locally moderate to steep slopes along stream channels.

Three freeways and several other arterial roadways cross the quadrangle. Northwesterly-trending U.S. Highway 101 intersects State Highway 17/Interstate Highway 880 in the northeast corner of the quadrangle. Highway 17 extends southwest through the central portion of the quadrangle and is the primary route through the Santa Cruz Mountains to the Pacific Ocean in this area. Interstate Highway 280 extends in an east-west direction across the center of the quadrangle. The Lawrence, San Tomas, and Almaden expressways trend north-south along the western margin, center, and eastern margin, respectively. A dense network of secondary roads and city streets lies between these major highways. The San Jose International Airport is located near the northern margin of the quadrangle.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth’s surface. For the San Jose West Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the U.S. Geological Survey (USGS, 1993). This DEM, which was prepared from the 7.5-minute quadrangle topographic contours based on 1948 and 1960 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

A slope map was made from the DEM using a third-order, finite-difference, center-weighted algorithm (Horn, 1981). The manner in which the slope map was used to prepare the zone map is described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

The primary source of bedrock geologic mapping used in this slope stability evaluation was the digital database "Preliminary Geologic Map of the San Jose 30 x 60 minute Quadrangle" prepared by the USGS (Wentworth and others, 1999). The 1:24,000-scale geology of the San Jose West 7.5-minute Quadrangle was obtained from this database. The Quaternary geologic mapping for the San Jose West Quadrangle was prepared by Knudsen and others (2000) at a scale of 1:24,000. Quaternary geology is discussed in detail in Section 1 of this report.

DMG geologists merged the surficial and bedrock geologic maps and databases and contacts between them were modified in some areas to resolve differences. Geologic reconnaissance was performed to assist in adjusting contacts and to review the lithology of geologic units and geologic structure. In the field, observations were made of exposures, aspects of weathering, and general surface expression of geologic units. In addition, the relationship of the various geologic units to the development and abundance of slope failures was noted.

The bedrock sequences in the San Jose 30 x 60 minute Quadrangle have been divided into eight fault-bounded structural blocks based on differing stratigraphic sequences and geologic history (Wentworth and others, 1999). Two of these structural blocks extend into the San Jose West 7.5-minute Quadrangle: the New Almaden Block and the Silver Creek Block. The following descriptions of bedrock units primarily are based upon Wentworth and others (1999) and on field reconnaissance by DMG geologists.

As noted above, most of the San Jose West Quadrangle is occupied by the alluviated Santa Clara Valley. Bedrock exposures are limited to the southwestern corner and close to the eastern margin in the southern half of the quadrangle. Only two bedrock units are exposed within the quadrangle.

Two small exposures of Coast Range Ophiolite (Jsp) mapped at the eastern boundary of the quadrangle represent the westernmost extent of the Silver Creek Block (Wentworth and others, 1999). This unit primarily consists of serpentinite and is the older of the two bedrock units exposed in the quadrangle. The places where rocks of the Coast Range Ophiolite are exposed in the San Jose West Quadrangle have very low relief, and no landslides were mapped in this unit.

In the southwestern corner of the San Jose West Quadrangle bedrock exposures within the New Almaden Block consist of non-marine Plio-Pleistocene Santa Clara Formation (QTsc) rocks. As described by Wentworth and others (1999), the rocks within this lenticular formation are highly variable in composition. They range from fluvial boulder to pebble conglomerate, sandstone, and siltstone, to thin-bedded lacustrine mudstone. Fossils, including fresh-water oysters, clams and snails, woody debris, plants, and vertebrate parts, are locally abundant in the lower beds. Upper beds include the Rockland ash unit. The Santa Clara Formation unconformably overlies older Miocene strata that are not exposed in the San Jose West Quadrangle. The age range of this formation overlaps that of the Silver Creek Gravels (Tsg) and the Packwood Gravels (QTp) of the Silver Creek Block within the adjacent San Jose East Quadrangle.

Pleistocene to Holocene surficial units unconformably overlie the bedrock units across most of the quadrangle. The oldest of these units consists of Quaternary older fan deposits (Qof) adjacent to the Santa Cruz Mountains. A discussion of the lithology and distribution of these units can be found in Section 1 of this report.

Structural Geology

The San Jose West Quadrangle is within the active San Andreas Fault system, which distributes shearing forces across a complex zone of primarily northwest-trending, right-lateral strike-slip faults that include the San Andreas, Hayward, and Calaveras faults. The San Andreas Fault is approximately two miles west of the San Jose West Quadrangle. The Hayward and Calaveras faults are approximately six and eight miles to the east of the quadrangle, respectively. Historical surface-rupturing earthquakes have occurred on all of these faults (Lawson, 1908; Keefer and others, 1980). Several oblique and reverse-slip faults, including the Sargent-Berrocal, Shannon, Monte Vista, and Santa Clara, are within or slightly west of the San Jose West Quadrangle along the base of the foothills. The mapped trace of the Monte Vista Fault trends northwesterly beneath the alluvial deposits along the northern margin of the Santa Cruz Mountains that form the uplands in this quadrangle (McLaughlin and others, 1991; Hitchcock and others, 1994; Campbell and others, 1995; McLaughlin and others, 2001).

Exposures of the Santa Clara Formation within the San Jose West Quadrangle are generally very poor, and structural data for this area are sparse. To the west in the Cupertino Quadrangle, this formation is faulted and intensely folded where it is closer to the San Andreas Fault (Brabb, 1983). However, based on limited field observations by DMG geologists, it appears that strata in the San Jose West Quadrangle dip shallowly to the northeast and are characterized by open folds and broad undulations. With regard to the occurrence and distribution of landslides in the San Jose West Quadrangle, it appears that the variable lithology and the lenticular character of the Santa Clara Formation may be more significant than the attitude of the bedding within the unit.

Landslide Inventory

An inventory of existing landslides in the San Jose West Quadrangle was prepared by field reconnaissance, analysis of stereo-paired aerial photographs and a review of previously published landslide mapping. Landslides were mapped and digitized at a scale of 1:24,000. For each landslide included on the map, a number of characteristics were compiled. These characteristics include the confidence of interpretation (definite, probable and questionable) and other properties, such as activity, thickness, and associated geologic unit. Landslides rated as definite and probable are carried into the slope stability analysis, and landslides rated as questionable are not carried into the slope stability analysis due to the uncertainty of their existence. The completed hand-drawn landslide map was scanned, digitized, and the attributes were compiled in a database. A version of this landslide inventory is included with Plate 2.1.

A total of fourteen existing landslides were mapped in this quadrangle, all within the Santa Clara Formation in the southwestern corner of the quadrangle. None of these landslides was assigned a definite confidence rating, four were considered probable, and ten were considered questionable. Aerial photos taken in 1939 (USDA) were the primary source of data because subsequent urban development has obscured landslides and other terrain features.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strengths. Generally, the primary source for shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear-strength data for the geologic units identified on the San Jose West geologic map were obtained from CalTrans, the cities of San Jose and Los Gatos, and the DMG's hospital-review program (see Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1. In addition, selected shear tests from adjoining portions of Calaveras Reservoir, Cupertino, San Jose East, and Los Gatos quadrangles were used to augment data for several geologic formations for which little or no shear test information was available within the San Jose West Quadrangle.

Shear strength data gathered from the above sources were compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction (average phi) or lithologic character. Average (mean and median) phi values for each geologic map unit and corresponding strength group are summarized in Table 2.1. For most of the geologic strength groups in the map area, a single shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Tables 2.1 and 2.2 and this map provides a spatial representation of material strength for use in the slope stability analysis.

Because of their close shear strengths, Qhf and Qof are assigned to the same strength group, along with many of the other Quaternary units with similar lithologies for which no shear-strength data are available. By the same reasoning, af, Qhl and Jsp are combined, along with several other Quaternary and fill units. The median values of phi have been combined for each group except for Group 2, where the sample population was great enough to use the mean.

Adverse bedding conditions can occur where the direction and magnitude of the dip of bedded rocks approach that of the surface slope. This was considered but could not be incorporated into the analysis since strike and dip measurements are not available for bedrock within or close to the quadrangle.

Existing Landslides

The strength characteristics of existing landslides (Qls) should be based on tests of the materials along the landslide slip surface. Ideally, shear tests of slip surfaces formed in each mapped geologic unit would be used. However, this amount information is rarely available, and for the preparation of the earthquake-induced landslide zone map, all landslides within the quadrangle are assumed to have the same slip-surface strength parameters. We collect and use primarily “residual” strength parameters from laboratory tests of slip surface materials tested in direct shear or ring shear test equipment. For the San Jose West Quadrangle, seven direct shear tests of slip surface materials from the southeast portion of the Cupertino Quadrangle were used. The results are summarized in Table 2.1.

SAN JOSE WEST QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name (1)	Number Tests	Mean/Median Phi (2) (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (3) (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	Qpf	27	35.8 / 36.0	35.8 / 36.0	905 / 800	- - -	36.0
GROUP 2	QTsc	41	29.5 / 27.5	29.5 / 27.5	919 / 680	- - -	29.5
GROUP 3	Qhf Qof	23 2	25.6 / 24.0 25.5 / 25.5	25.6 / 24.0	674 / 550	Qa, gq, Qha, Qhc, Qht, Qhty, Qt	24.0
GROUP 4	Jsp Qhl af	8 5 6	22.9 / 21.5 23.2 / 22.0 18.5 / 18.0	21.6 / 21.0	640 / 500	-ac, alf Qhff Qhly	21.0
GROUP 5	Qls	7	13.4 / 14.0	13.4 / 14.0	465 / 538	- - -	14.0

Notes:
(1) Formations for strength groups from Wentworth and others (1999); Knudsen and others (2000).
(2) Phi is the angle of internal friction.
(3) C is cohesion.

Table 2.1. Summary of the Shear Strength Statistics for the San Jose West Quadrangle.

SHEAR STRENGTH GROUPS FOR THE SAN JOSE WEST 7.5-MINUTE QUADRANGLE				
GROUP 1	**GROUP 2**	**GROUP 3**	**GROUP 4**	**GROUP 5**
Qpf	**QTsc**	**gq**	**ac, af**	**Qls**
		Qa, Qha	**alf**	
		Qhc, Qhf	**Qhff**	
		Qht, Qhty	**Qhl, Qhly**	
		Qof, Qt	**Jsp**	

Table 2.2. Summary of Shear Strength Groups for the San Jose West Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity". For the San Jose West Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.9 - 7.9
Modal Distance:	7.8 - 17.2 km
PGA:	0.54 - 0.72 g

The strong-motion record selected for the slope stability analysis in the San Jose West Quadrangle is the Lucerne record from the 1992 Landers earthquake of moment magnitude (M_W) 7.3. This record had a source to recording site distance of 1.1 km and a PGA of 0.8 g. Although the distance and PGA do not fall within the range of the probabilistic parameters, this record is considered sufficiently conservative to be used in the stability analyses. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was determined by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm are used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and a DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.142, 0.182 and 0.243 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant in the San Jose West Quadrangle.

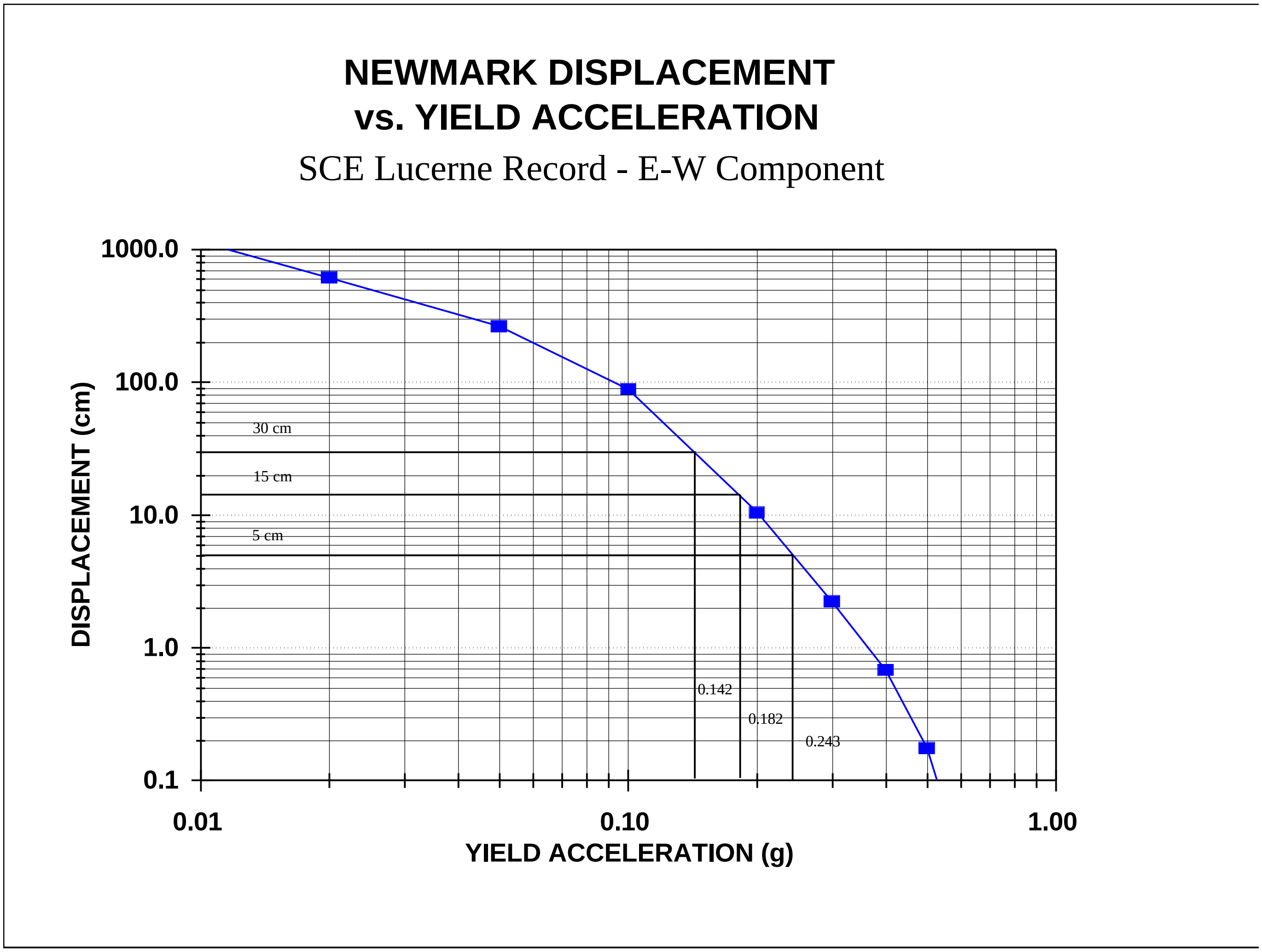

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the Lucerne Record from the 1992 Landers Earthquake.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1) g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure, α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.142 g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned (H on Table 2.3)

2. If the calculated yield acceleration fell between 0.142 g and 0.182 g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned (M on Table 2.3)

3. If the calculated yield acceleration fell between 0.182 g and 0.243 g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned (L on Table 2.3)

4. If the calculated yield acceleration was greater than 0.243 g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned (VL on Table 2.3)

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

SAN JOSE WEST QUADRANGLE HAZARD POTENTIAL MATRIX

Geologic Material Group	MEAN PHI	SLOPE CATEGORY (% SLOPE)							
		I	II	III	IV	V	VI	VII	VIII
		0 - 12	13 - 19	20 - 25	26 – 31	32 - 37	38 - 45	46 - 51	>51
1	36.0	VL	VL	VL	VL	VL	VL	L	H
2	29.5	VL	VL	VL	VL	L	H	H	H
3	24.0	VL	VL	L	M	H	H	H	H
4	21.0	VL	L	M	H	H	H	H	H
5	14.0	M	H	H	H	H	H	H	H

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the San Jose West Quadrangle. Shading indicates hazard potential levels included within the zone of required investigation. H = High, M = Moderate, L = Low, VL = Very Low.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.

2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

Existing landslides typically consist of disrupted soils and rock materials that are generally weaker than adjacent undisturbed rock and soil materials. Previous studies indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most pronounced in steep head scarp areas and at the toe of existing landslide deposits. Although reactivation of deep-seated landslide deposits is less common (Keefer, 1984), a significant number of deep-seated landslide movements have occurred during, or soon after, several recent earthquakes. Based on these observations, all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by DMG (McCrink and Real, 1996), earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicates earthquake displacements of 5 centimeters or greater. Areas with a Very Low hazard potential, indicating areas with less than 5 centimeters displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 5 is included for all slope gradient categories. (Note: Geologic Strength Group 5 includes all mappable landslides with a definite or probable confidence rating).

2. Geologic Strength Group 4 is included for all slopes steeper than 12 percent.

3. Geologic Strength Group 3 is included for all slopes steeper than 19 percent.

4. Geologic Strength Group 2 is included for all slopes steeper than 31 percent.

5. Geologic Strength Group 1 is included for all slopes greater than 45 percent.

This results in less than one percent of the land area within the quadrangle lying within the earthquake-induced landslide hazard zone for the San Jose West Quadrangle. The zone is restricted to areas along creek banks in the central portion of the quadrangle and in the steeper slopes of the low-lying hills.

ACKNOWLEDGMENTS

The California Department of Transportation (CalTrans) and the cities of San Jose and Los Gatos assisted by making their files available to us for assembling shear-strength data. At DMG, Ellen Sander and Ian Penny digitized sample locations and updated the shear-test database. Barbara Wanish, Terilee McGuire, Ross Martin, Lee Wallinder, and Bob Moscovitz provided invaluable GIS and database support. Mark Wiegers and Tim McCrink gave helpful advice and provided additional technical assistance.

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AIR PHOTOS

United States Department of Agriculture (USDA) dated 7-31-39, photos CIV 286-18 through 20.

WAC Corporation, Inc. dated 4-13-99, photos WAC-C-99CA, 2-70 through 73, and 2-134 through 137.

APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
CalTrans	27
City of Los Gatos	1
City of San Jose	7
Division of Mines & Geology	4
Total Number of Shear Tests	39

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the San Jose West 7.5-Minute Quadrangle, Santa Clara County, California

By

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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the “Simple Prescribed Parameter Value” method (SPPV) described in the site investigation guidelines (California Department of Conservation, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG’s Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

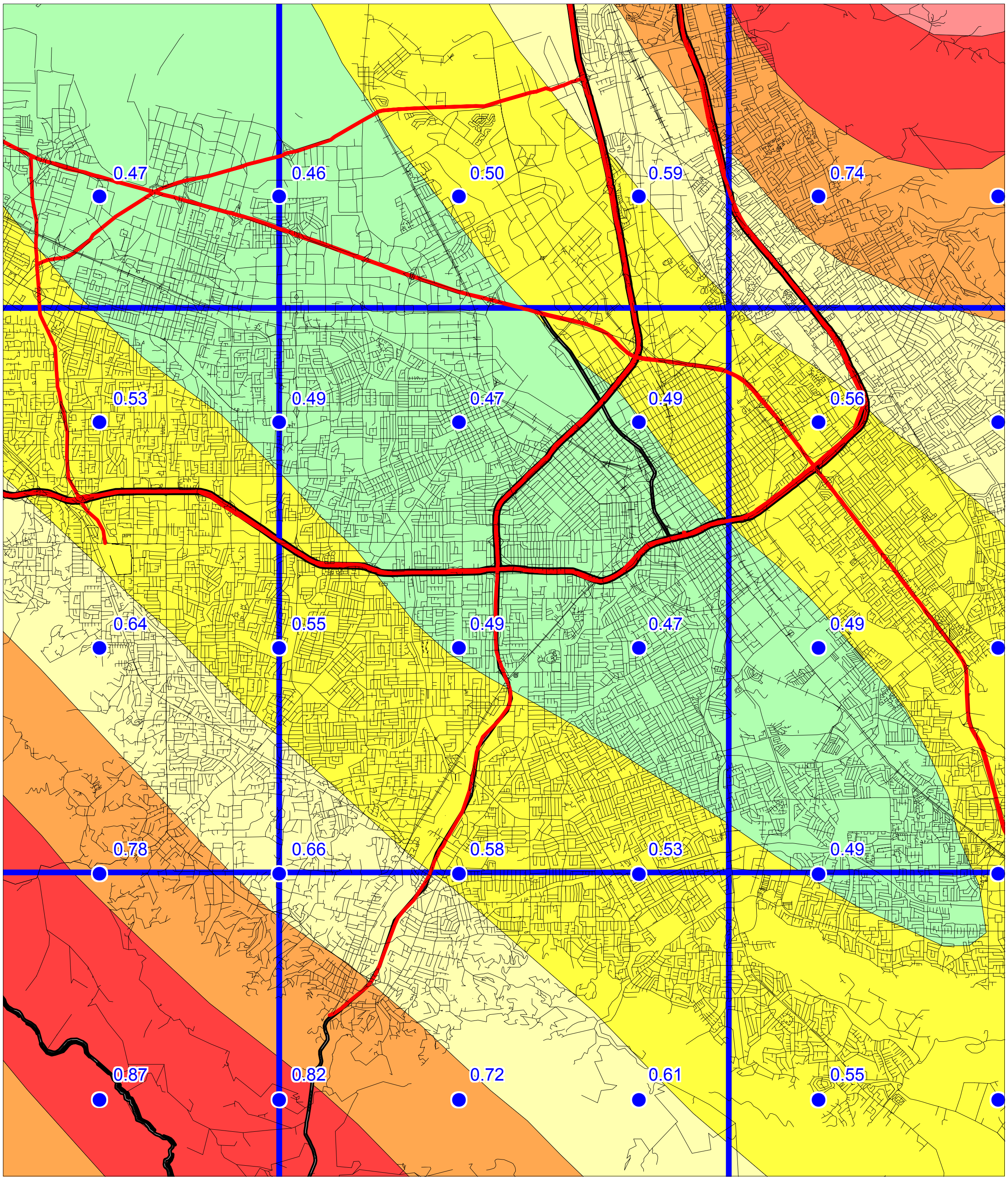
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent

SAN JOSE WEST 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 1.5 3

Miles

Department of Conservation
Division of Mines and Geology

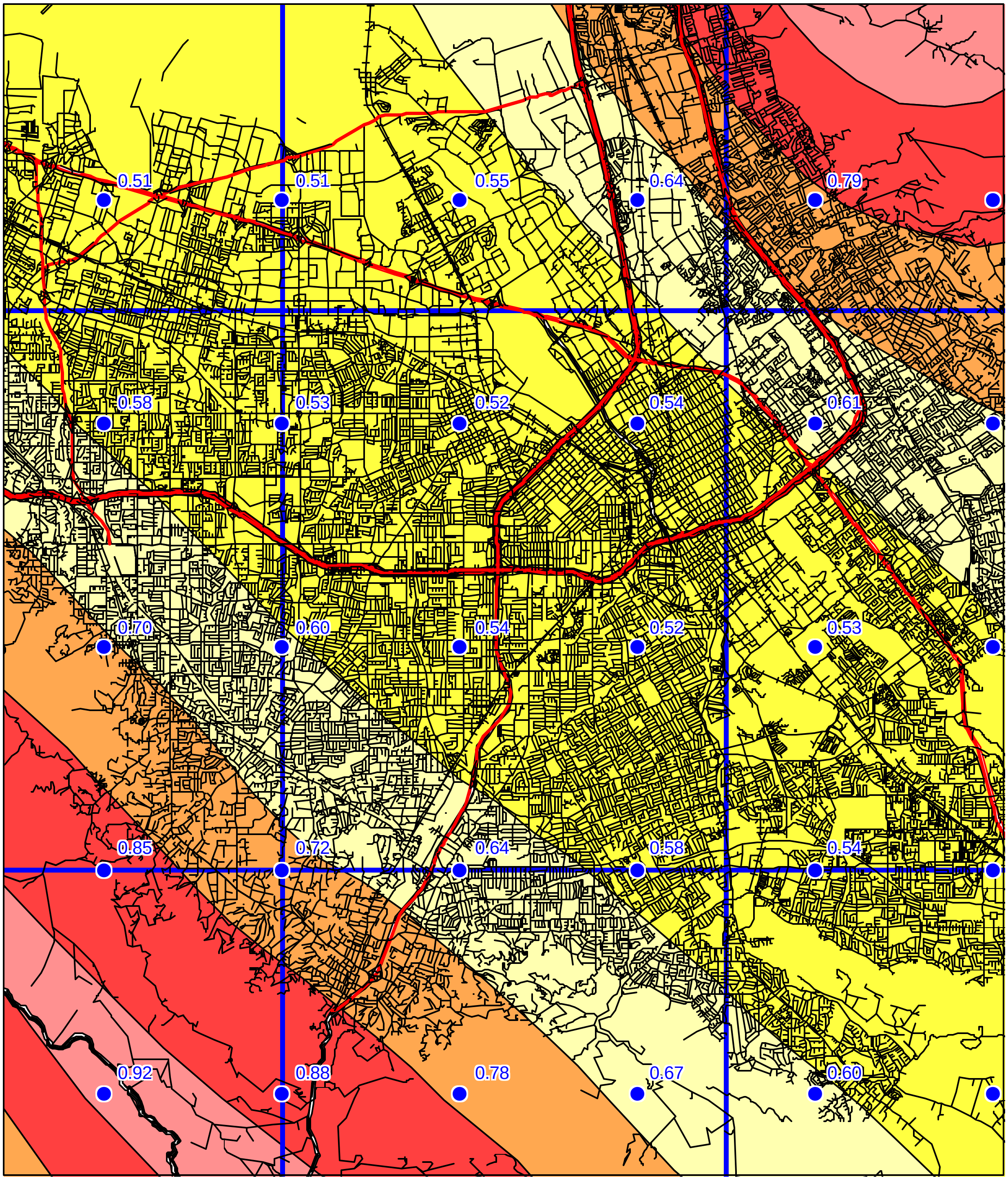
Figure 3.1

SAN JOSE WEST 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



0 1.5 3

Miles

Department of Conservation
Division of Mines and Geology

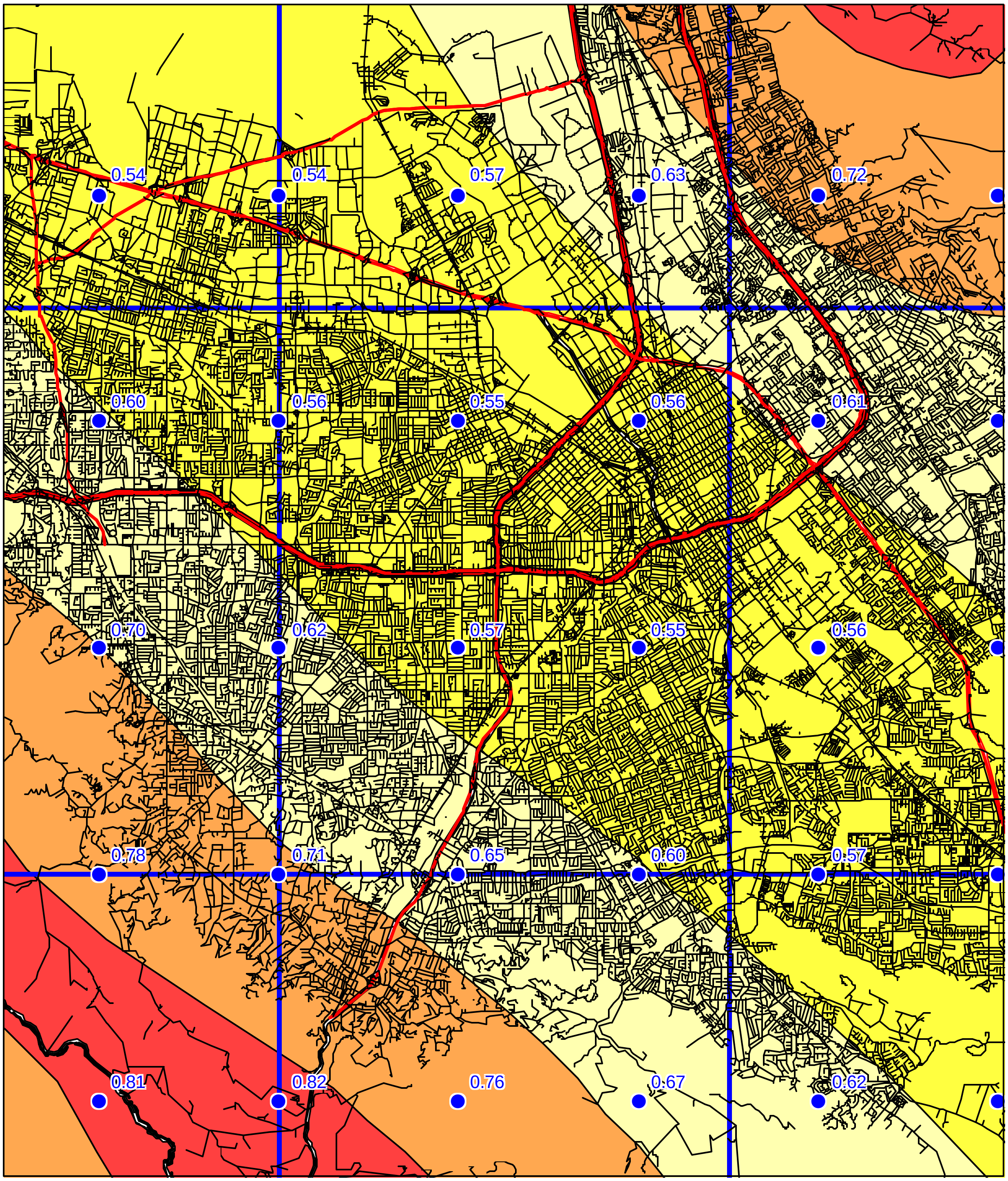
Figure 3.2

SAN JOSE WEST 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works © 1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the "simplified Seed-Idriss method" of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a "magnitude-weighted" ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

SAN JOSE WEST 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

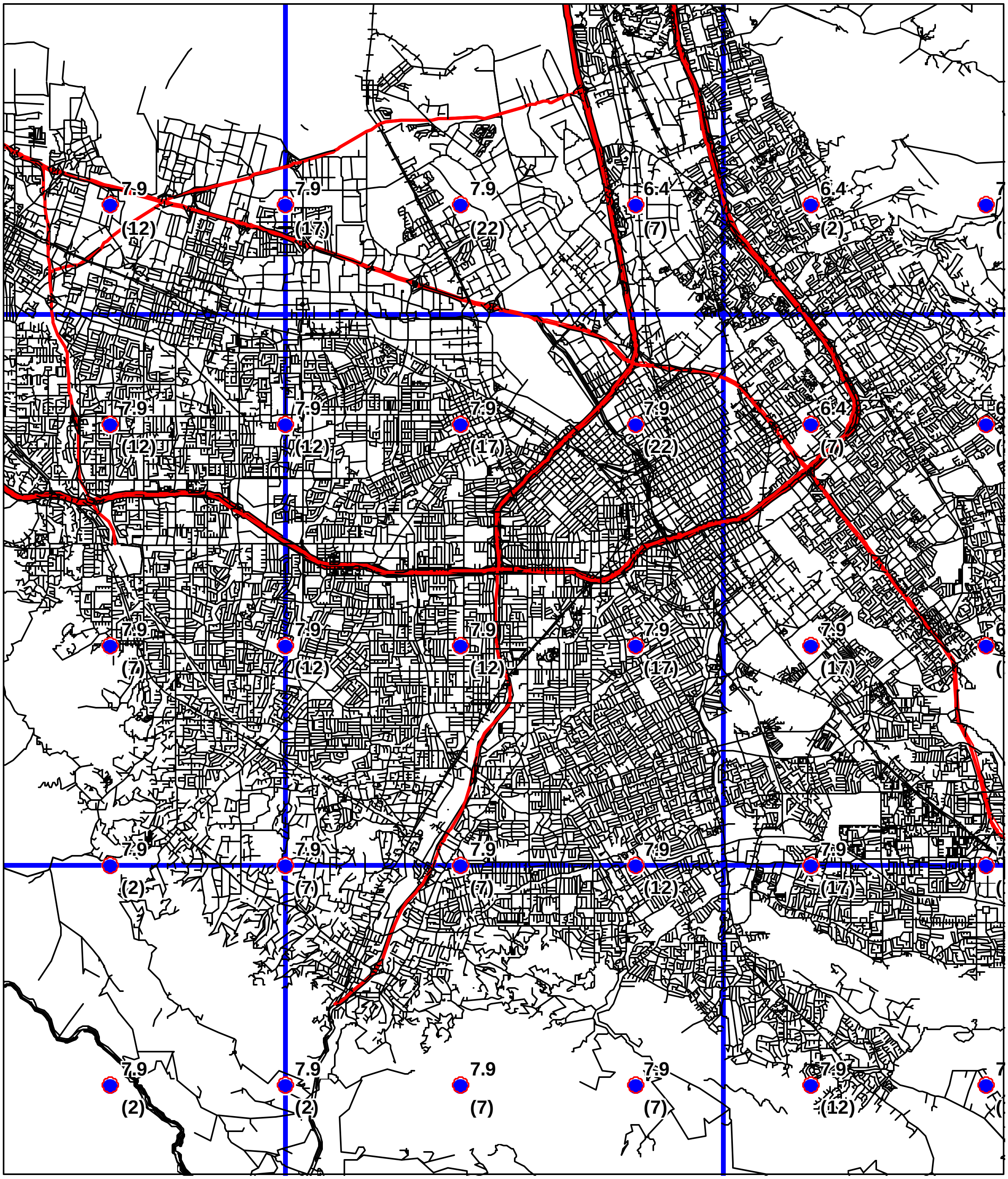
10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE

Magnitude (Mw)

(Distance (km))



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 1.5 3

Miles

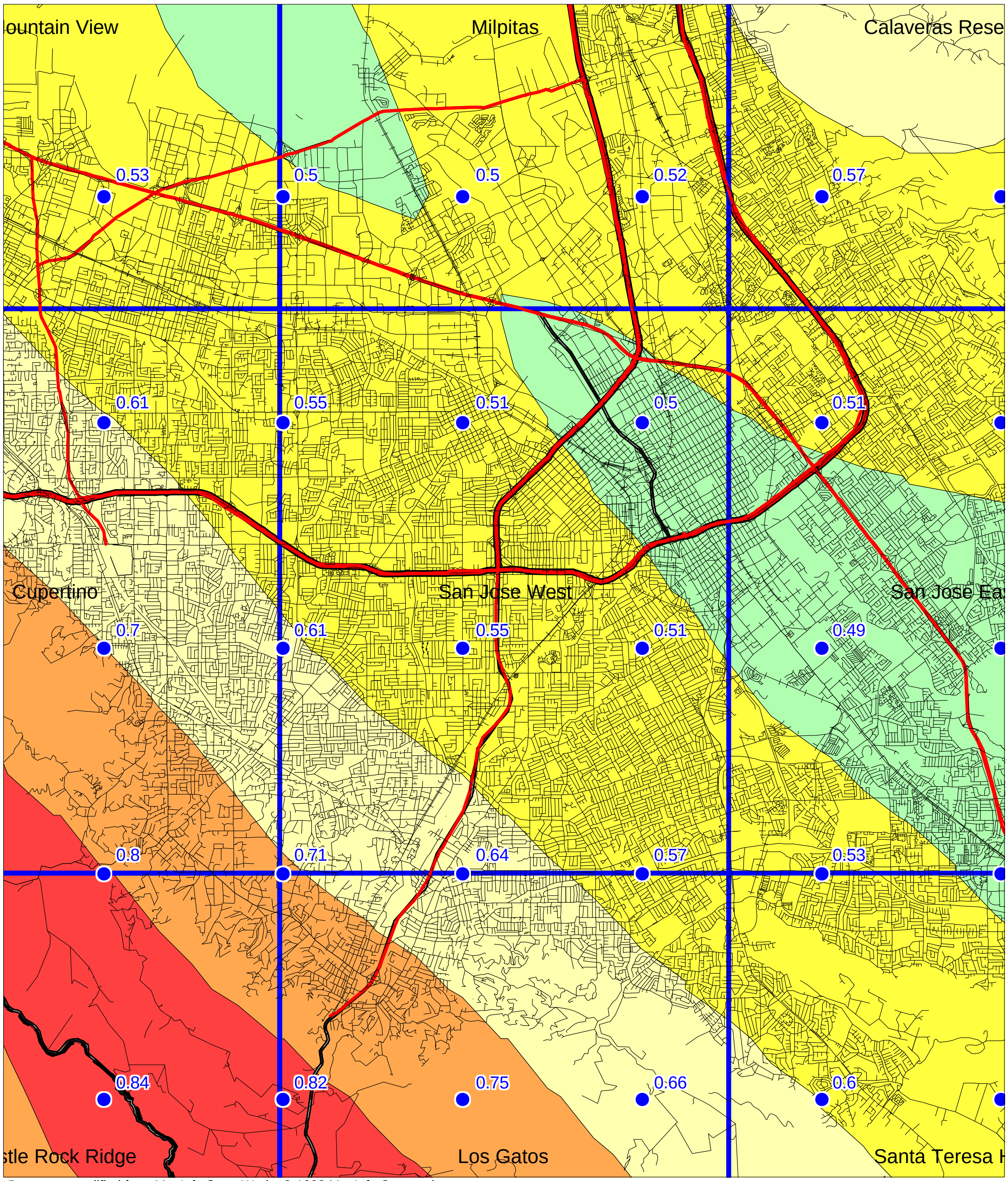
Department of Conservation
Division of Mines and Geology
Figure 3.4

SAN JOSE WEST 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g) FOR ALLUVIUM

2001

LIQUEFACTION OPPORTUNITY



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 1.5 3

Miles

Department of Conservation
Division of Mines and Geology

Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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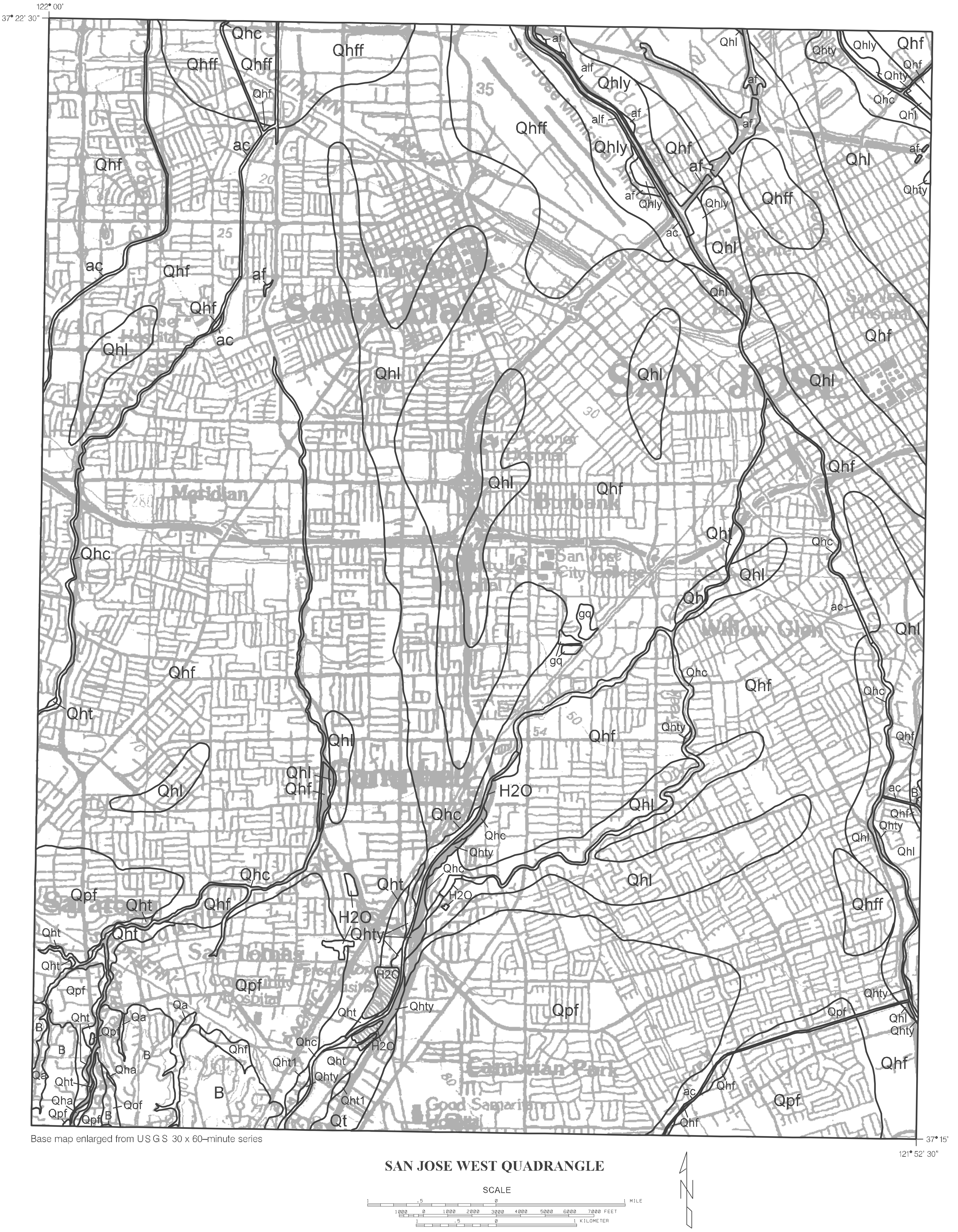
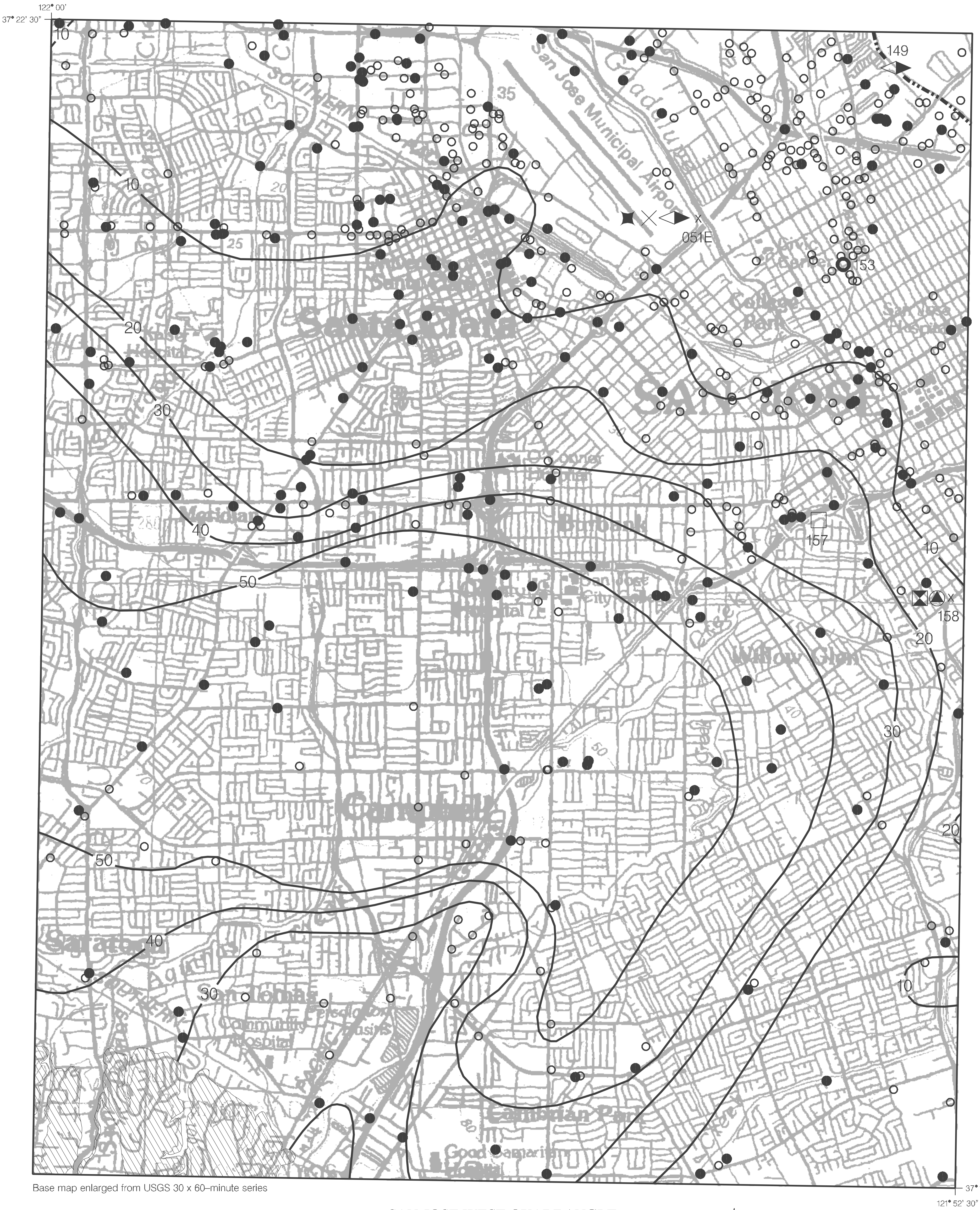


SAN JOSE WEST QUADRANGLE

SCALE

B = Pre-Quaternary bedrock.
See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

Plate 1.1. Quaternary geologic map of the San Jose West Quadrangle, California. *Modified from Knudsen and others (2000).*



Base map enlarged from USGS 30 x 60–minute series

SAN JOSE WEST QUADRANGLE

SCALE

1 MILE

1000 FEET

1 KILOMETER

Historical Ground Failures (from Knudsen and others, 2000)

- X — Location of multiple ground effects. (See corresponding symbols)
- Cracks in streets
- Disturbed well
- Sand boil
- Miscellaneous effects
- Absence of ground failure noted
- Ground settlement
- Reach of Coyote Creek along which multiple failures were recorded. Symbol shows failure type.
- Lateral spread
- 152 — Number assigned to ground failure site (adapted from Youd and Hoose, 1978, and Tinsley and others, 1998, by Knudsen and others, 2000).
- Bedrock
- 10 — Depth to ground water, in feet
- Geotechnical boreholes used in liquefaction evaluation
- Ground–water level data provided by the Santa Clara Valley Water District

Plate 1.2 Depth to historically high ground water, historical liquefaction sites, and locations of boreholes, San Jose West 7.5-minute Quadrangle, California

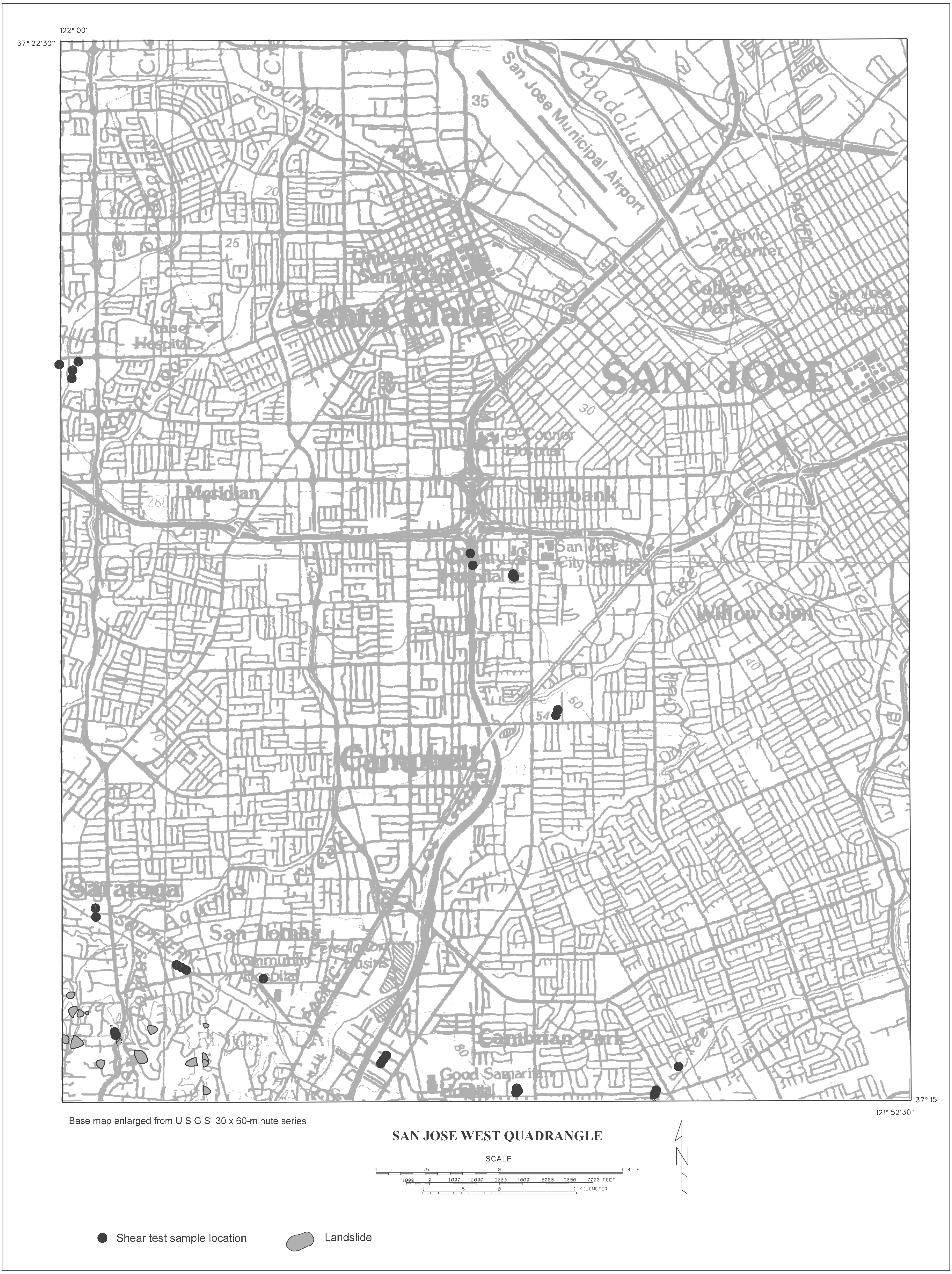


Plate 2.1 Landslide inventory and shear test sample locations, San Jose West 7.5-minute Quadrangle.